GRAPHING

A great deal of physics depends of deriving mathematical relationships from data. This can be done by drawing a graph and then calculating the equation for the best fit line through the data. The best fit line is the line that is close to most of the data.

You have already dealt with calculating equations of lines in mathematics when you drew a graph and described it in the form of:

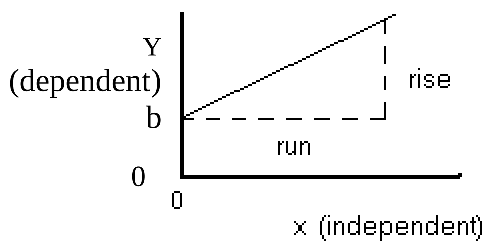
$$y = mx + b$$

This equation describes a direct relationship and will frequently be adequate in dealing with data.

In the course of this exercise you will also learn how to deal with exponential relationships, inverse relationships and some graphing conventions that are unique to science.

I Direct Relationships ($y \propto x$)

This is the graphing form that you are familiar with in math. In this relationship, when x doubles y also doubles. When you are plotting data, the independent variable is usually plotted on the horizontal axis and the dependent variable is on the vertical axis.

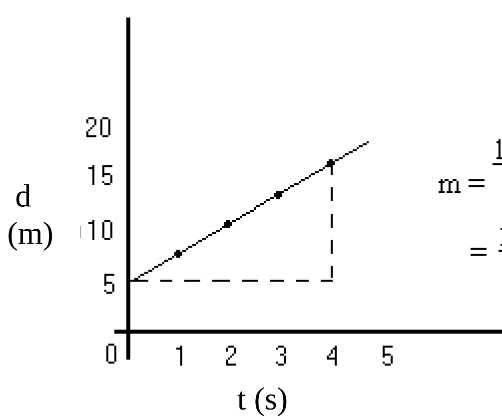


m is the slope (rise/run)
b is the y intercept

In physics we no longer label the axis as x & y, but instead they are named after the physical quantities involved. These quantities also have unites which must be included beside the axis.

A graph of the following data is shown below.

distance, d (m)	5	8	11	14	17
time, t (s)	0	1	2	3	4



$$m = \frac{12m}{4s} = \frac{3m}{s}$$

d = 3 m/s t + 5m

Hints for Successful Graphing

1. Title the graph.
2. Name and label the axis with the appropriate quantities and units.
3. Mark the origin.
4. Use at least half a page for your graph.
5. Choose an axis scale that allows you to create a line at approximately 45° to either axis.
6. Draw a line that averages the errors. Do not join the points, but draw a line that has the same number of points below the line as above the line.
7. Draw a large slope interval and measure the slope.
8. State the equation for the line and include units for the slope and intercept.

Practice Problems

1. Graph the following data and state an equation for each graph.

   a) The circumferences and diameters of various circles were measured and recorded. What is the relationship between circumference and diameter?

Circumference, c (cm)	3.1	6.3	8.4	12.6	15.7
Diameter, D (cm)	1.0	2.0	3.0	4.0	5.0

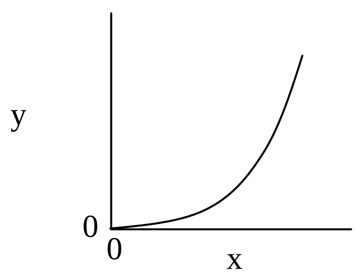
   b) A car accelerated from 0 to 34 m/s in 7 seconds. Plot a graph of the trip and find the relationship between velocity and time.

Velocity, v (m/s)	0	5	11	14	22	26	30	34
Time, t (s)	0	1	2	3	4	5	6	7

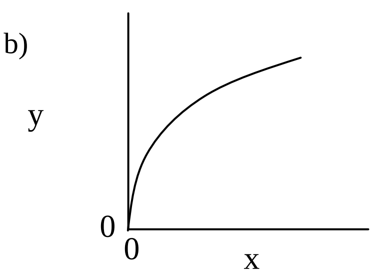
II Exponential Relationships ($y \propto x^a$)

Another very common type of graph is called an exponential relationship or power relationship. When these relationships are initially encountered they will look like:

a)



b)



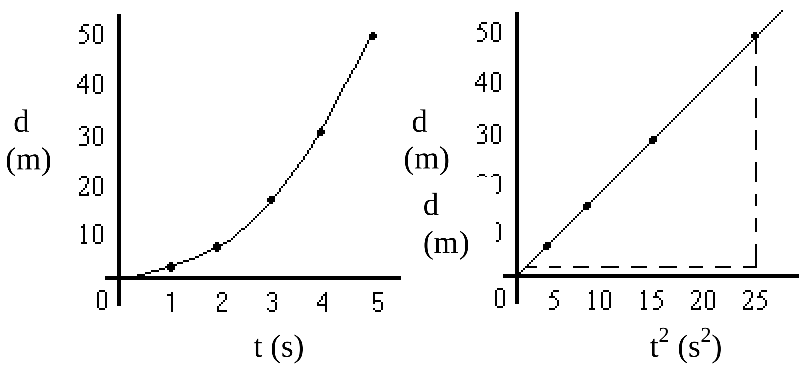
In order to write an equation for either graph, you must first straighten the line by raising the values of one axis to a higher power. Decide which axis needs to be increased more rapidly to keep up with the other and square that one. In graph a) above square the value on the horizontal and plot y vs x^2. To straighten graph b) plot y^2 vs x. when you do this you not only square the values but also the **label**, **symbol** and the **units** for that axis.

For example, you are given the following data:

displacement, d (m)	0	2	8	18	32	50
time, t (s)	0	1	2	3	4	5

When graphed it produces a curve. To obtain an equation from the graph, we need a linear relationship. If we calculate the square of all the x data, in this case the time data, then graph displacement verses time square, we will obtain a linear function.

displacement, d (m)	0	2	8	18	32	50
time, t (s)	0	1	2	3	4	5
if we square the time data, we obtain:						
(time)^2 ,t^2 (s^2)	0	1	4	9	16	25



m = 50 m/25s^2

= 2.0 m/s^2

Once the graph has been straightened, you can state the equation for the line by using the format given in part 1.

$$d = 2.0 \text{ m/s}^2\ t^2$$

Note that this is the equation of the both the curve and the straight line.

Practice Problem

1. The areas and diameters of various circles were recorded. Plot a graph and find the relationship between area and diameter.

Area, A (cm^2)	0.8	3.1	7.1	12.6	19.6
Diameter, D (cm)	1.0	2.0	3.0	4.0	5.0

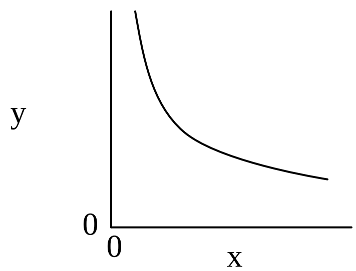
2. Forces were applied to threads of various thickness until each thread broke. Determine the relationship between breaking force and diameter for this material.

Breaking force, F (N)	7.8	29.4	69.6	124.5	198	282
Diameter, D (mm)	1.0	2.0	3.0	4.0	5.0	6.0

III Inverse Relationships ($y \propto 1/x$)

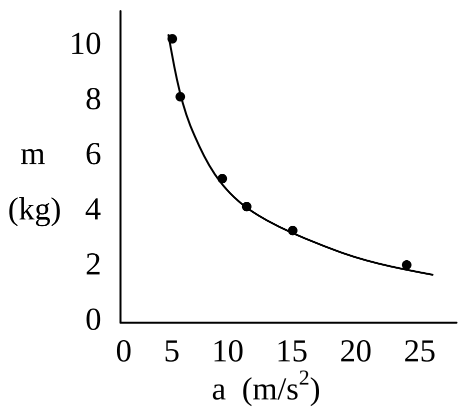
The third type of relationship is called an inverse relationship. When one quantity increases the other quantity decrease proportionally. Another way of saying the same thing is that the product of the two variables is a constant, $yx = k$. You can straighten the graph by calculating the inverse of one of the quantities and then graphing y vs 1/x.

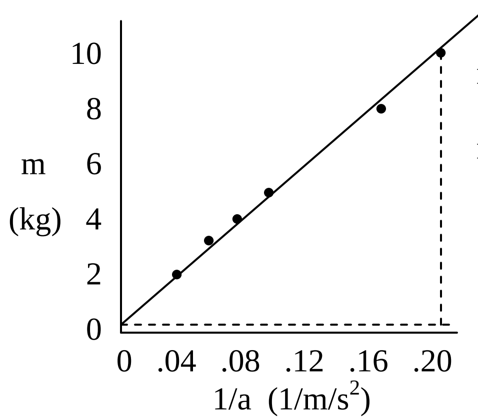
A graph of this relationship will originally look like the following:



You must straighten this graph in order to write an equation for it. To do this, plot y vs 1/x. It is usually more convenient to invert the values on the horizontal axis although mathematically yuou could correctly invert either axis. Again note that when you do this that you have inverted the label, the symbol, the units as well as the numbers which are now expressed as decimals. An example of an inverse relationship is shown below.

Mass, M (kg)	2	3	4	5	8	10
Acceleration, a (m/s^2)	24	16	12.5	10	6	5
1/a (s^2/m)	0.04	0.06	0.08	0.10	0.17	0.20





m (slope) = $10kg/0.2s^2/m$
$= 50\ kgm/s^2$
m(mass) = $50\ kgm/s^2\ 1/a$

Practice Problems

1. A device is set up to measure the frequency and wavelengths produced by a piano. Plot a graph to show the relationship between frequency and wavelength. Assume frequency is the independent quantity.

Wavelength, λ	(m)	1.5	1	0.6	0.38	0.3	0.25
Frequency, f	(cycles/s)	200	300	500	800	1000	1200